Response To Office Action Mailed February 27, 2003

A. Pending Claims

Claims 28-32 were rejected. Claims 28 and 32 have been amended. Claims 28 – 32 are pending in the case.

B. The Claims Are Supported by the Specification Pursuant to 35 USC §112, First Paragraph

The Examiner rejected claims 28 – 32 pursuant to 35 U.S.C. §112, first paragraph, for allegedly failing to comply with the written description requirement. The Examiner asserts that the language of amended claim 28, which recites the limitation of implanting ions of Ar, Ne or He into the regions of the substrate such that "regions of the silicon substrate are exposed directly to the implantation source" is not supported by the specification.

The language of claim 28 has been amended for clarification. Applicant submits that the claim amendments made herewith are supported by the specification and comply with the written description requirement of 35 U.S.C. §112, first paragraph. Applicant respectfully requests the withdrawal of the Examiner's rejections on these grounds.

C. The Claims Are Not Obvious Pursuant To 35 U.S.C. 103(a)

The Examiner rejected claims 28-30 under 35 U.S.C. 103(a) as obvious over Japanese Patent No. JP 07-094503 granted to Yamanishi (hereinafter referred to as Yamanishi) in view of Chittipeddi (US Patent No. 5,918,116, previously cited). Applicant respectfully disagrees with these rejections.

In order to reject a claim as obvious, the Examiner has the burden of establishing a *prima*

facie case of obviousness. *In re Warner et al.*, 379 F.2d 1011, 154 U.S.P.Q. 173, 177-178 (C.C.P.A. 1967). To establish a *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981, 180 U.S.P.Q. 580 (C.C.P.A. 1974), MPEP § 2143.03.

The Examiner states:

> Regarding claims 28 and 29, Yamanishi discloses implanting ions of a chemical species such as argon (Ar) into predetermined regions of a silicon substrate (21) wherein the implanted regions of the substrate are exposed directly onto the implantation source. The surface of the substrate is then oxidized to form a gate oxide layer of non-uniform thickness and MOS transistors are formed over the gate oxide layer. Yamanishi does not explicitly disclose implanting the species at an implantation energy of 2 – 15 keV. However, Yamanishi states that the process parameters of the ion implantation and the oxidation can be tailored according to the thickness of oxide that is desired. Like Yamanishi, Chittipeddi discloses a process of forming gate oxides of non-uniform thickness on a silicon substrate by implanting regions of the substrate with ions of a chemical species in order to increase the oxidation rate of these regions. Chittipeddi discloses that these ions may be implanted at energies ranging from 5 – 500 keV. At the time of the invention, it would have been obvious to one of ordinary skill in the art to implant the ions of Yamanishi with an energy in the range of 5 – 15 keV because Yamanishi states that the ion implantation process parameters may be varied according to the thickness of oxide desired for a particular purpose and Chittipeddi teaches that implantation energies within this range can successfully accomplish an increase in the oxidation rate of a silicon substrate.

The present invention is drawn to a process for forming a semiconductor device comprising a plurality of MOS transistors at predetermined regions of a silicon substrate. Amended claim 28 recites a combination of features that include:

> implanting, in the predetermined regions of the silicon substrate, a chemical species with an implantation energy between 2 and 15 keV, wherein the chemical species comprises Ne or He;
> oxidizing the surface of the silicon substrate to form a gate oxide layer of non-uniform thickness; and

> forming MOS transistors at the predetermined regions of the silicon substrate, wherein the oxidized layer at the predetermined regions forms the gate oxide layer of the MOS transistors.

Yamanishi appears to teach a method whereby nitrogen atoms are implanted in a predetermined region of a silicon substrate with an implantation energy of 58.8 keV and an implantation dose of $5x10^{15}$ atoms/cm^2, forming a nitrogen-implanted region 24. A thermal oxidation is performed, resulting in a thin silicon oxide layer 26 and a thick silicon oxide layer 27 (Examiner is asked to refer to Yamanishi, Fig. 4). Applicant believes that the method taught by Yamanishi differs from that which is presently claimed, insofar as Yamanishi teaches a supplementary step of implanting nitrogen ions in the silicon substrate while failing to teach the implantation of He and Ne. Moreover, Yamanishi appears to teach an implantation energy outside the range of that which is presently claimed (namely, 5 – 15 keV).

Applicant submits that implanting nitrogen ions in the silicon substrate according to Yamanishi's teachings is disadvantageous. In reference to the article "Formation of Ultrathin Nitrided SiO_2 Oxides by Direct Nitrogen Implantation into Silicon" (Soleimani et al., *J. Electrochem. Soc.*, 1998, cited by Applicant), Applicant's specification recites:

> The latter process has serious drawbacks since the high dose of implanted nitrogen (>10^{15} atoms/cm^2) inevitably leads to the degradation of the thin gate oxide layer. This drawback is all the more problematic when the implanted regions are in the majority on the substrate and the thinner the oxide layer is thereon (and therefore the more sensitive it is to degradation problems). (Specification, page 2, lines 20 – 27).

Moreover, the use of chemical species comprising Ne or He in the implantation step results in the formation of a porous silicon substrate, which enhances the diffusion of oxygen and increases the rate of oxidation of the semiconductor crystalline substrate. Applicant submits that the unexpected advantage of using He and Ne in this step to produce the gate oxide layer is neither taught nor suggested by the references taken either alone or in combination.

Similarly, neither the cited sections of Chittipeddi, nor Chittipeddi's disclosure teach

implanting Ne or He onto a silicon substrate. Instead, the reference appears to teach the implantation of silicon, fluorine or arsenic. Page 3, lines 9 – 13 of Applicant's specification recites:

> Although the implantation of phosphorous or arsenic increases the rate of oxidation of a silicon substrate, these species have the drawback, however, of being dopants of silicon, something which is not always desirable.

The Examiner further asserts that the use of an implantation energy that falls within the range of 2 – 15 keV is anticipated by the combination of the teachings of Yamanishi and Chittipeddi. The Examiner argues Yamanishi teaches that the process parameters of the ion implantation step can be tailored according to the desired oxide thickness. Applicant submits however, that Yamanishi does not teach how to adjust these parameters.

Applicant further submits that the relationship between oxide thickness and implantation parameters (i.e. dose and energy) is not intuitive. Applicant discloses in Table I that, under conditions where an implantation dose and energy of Ne or He is $5x10^{14}$ atoms/cm^2 and 2 keV the thickness of the resulting oxide layer is 5.66 nm. However, when the implantation energy is increased to 80 keV, the thickness of the resulting oxide layer is 6.00 nm. Thus, increasing the implantation energy by a factor of 40 has only a minimal effect on oxide thickness.

Conversely, under conditions where an implantation dose and energy of Ne or He are $5x10^{16}$ atoms/cm^2 and 10 keV, respectively, the thickness of the oxide layer formed is 12.3 nm. When the implantation energy is elevated to 80 keV however, the thickness of the oxide layer formed decreases by 10.6% to 11.00 nm.

Applicant therefore asserts that, at the time the invention was made, the range of optimal values for implantation energy and Ne or He implantation dosage used to achieve a desired oxide layer thickness would not have been obvious to one of ordinary skill in the art. Indeed, the implantation of Ne or He results in damaged regions of the silicon substrate that are comprised of Ne or He bubbles within an amorphous layer of the silicon. During the thermal treatment

required for oxide layer growth, isotropic diffusion of these bubbles and re-growth of the amorphous silicon layer occurs. Both these phenomena lead to a decrease in the thickness of the damaged region and to the formation of larger argon bubbles by percolation. These phenomena depend on thermal conditions applied (such as oxidation temperature and temperature ramp up and ramp down rates) and are complex, thus making prediction of the thickness under varying conditions extremely difficult.

For at least the reasons cited above, Applicant submits that neither Yamaishi nor Chittipeddi, taken separately or in combination, teach or suggest the combination of features of claim 28. Applicant further asserts that claims 28 – 30 are patentable over the cited art pursuant to 35 USC §103(a), and respectfully requests the removal of rejections on these grounds.

The Examiner also rejected claims 31 and 32 pursuant to 35 USC §103(a) as allegedly being unpatentable over Yamanishi and Cittipeddi in view of US Patent No. 5, 215, 934) granted to Tzeng. Applicant respectfully traverses these rejections.

If an independent claim is nonobvious under 35 U.S.C. 103, then any claim depending therefrom is nonobvious. *In re Fine*, 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988).

Applicant asserts that, for at least the reasons cited above, the combination of cited art fails to render amended claim 28, or any claims depending thereon, obvious. Applicant respectfully requests withdrawal of the rejection of claims 31 and 32.

E. <u>Summary</u>

Based on the above, Applicant submits that all claims are now in immediate condition for allowance. Favorable reconsideration of the claims is therefore respectfully solicited.

Applicant believes that no fees are due in association with the filing of this document. If any extension of time is required, Applicant hereby requests the appropriate extension of time. If any fees are required, please charge those fees to Meyertons, Hood, Kivlin, Kowert & Goetzel, P.C. Deposit Account Number 50-1505/5310-03000/EBM.

Respectfully submitted,

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